



(Formerly Advani-Oerlikon Ltd.)

Webinar on Welding Defects

ADOR WELDING LIMITED

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Presenter – Rohit Raut

- Qualification – B.Tech in Material Science and Metallurgy
- 7 Years experience in welding
- Currently Deputy Manager, Technology Development Centre for Consumables in Ador Welding Limited, Pune
- Handling Product & Process development, Technical Support, etc.
- Experience in Product development of consumables, Training, Development of Consumable Manufacturing Process

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Instructions regarding Webinar

- The webinar will follow presentation on the topic followed by questions and answer session.
- During presentation put your mics on mute mode.
- Also put your video off during presentation and the question and answer session.
- Do not share your screen during presentation.
- You can ask questions using Chat window anytime during presentation. I will discuss these questions during Q & A session.
- Using chat, put your questions using option of visible to everyone (public chat). This will avoid repeat of questions.
- My mail id and phone numbers are give a the end of presentation, to ask any doubts which remain after the allotted time.



What Is A Welding Defect ?

1. The defects in the weld can be defined as irregularities in the weld metal produced due to incorrect welding parameters or wrong welding procedures or wrong combination of filler metal and parent metal. It can simply be defined as:
2. “Defects introduced during welding beyond the acceptance limit that can cause a weld to fail”.
3. A defect does not allow the finished joint to withstand the required strength (load).





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Failure Due To Welding Defect On %Age Basis

According to the American Society of Mechanical Engineers (ASME) welding defect causes are broken down into the following % age:-

- 41% poor process conditions
- 32% operator error
- 12% wrong technique
- 10% incorrect consumables and
- 5% bad weld grooves.





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Presence Of Welding Defects: Action

What should be done when Welding-defects are detected?

1. One should reject the items and put them temporarily on hold.
2. One should determine the cause and try to implement a corrective action to avoid future reoccurrence.
3. Then an authorized professional should determine, if the defects are repairable or not.

If yes, by which procedure. Standard procedures may be approved for routine application.





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Evaluation Welding Defects

All discontinuities are not defects. Discontinuities are rejectable only if they exceed specification requirements

Radiographic standards used for evaluation of weld defects:-

- IIW standards
- ASTM standards

*Acceptance standards vary with service requirements





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IIW STANDARDS

Five IIW standards:

—Black

—Blue

—Green

—Brown

—Red

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Black

- A homogeneous weld or a weld with a few small scattered gas cavities

Blue

- Very slight variation from homogeneity in the form of one or more of the following defects:-

–Cavity

–Shrinkage cavity

–Slag inclusion

–Undercut

Green

- Slight variation from homogeneity in the form of one or more of the following defects:-

–Gas cavity

–Shrinkage cavity

–Slag inclusion

–Undercut

–Incomplete penetration

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Brown

- Marked deviation from homogeneity in the form of one or more of the following defects:-

–Gas cavity

–Shrinkage cavity

–Slag inclusion

–Undercut

–Incomplete penetration

–Lack of fusion

Red

- Gross deviation from homogeneity in the form of one or more of the following defects:-

–Gas cavity

–Shrinkage cavity

–Slag inclusion

–Undercut

–Incomplete penetration

–Cracks





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Specified welding defects level as per ASTM E- 390 Vol-II

- Defects not allowed:-

- Shrinkage /Crack

- Lack of Fusion

- Burn through

- Elongated Porosity

ASTM STANDARDS

- Defects allowed:-

- Incomplete Penetration up to level-II

- Slag Inclusion up to Level-III

- Undercut up to level-IV

- Porosity:

- Coarse scattered Porosity up to level-II

- Cluster Porosity up to Level-III

- Fine scattered Porosity up to Level-IV

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CLASSIFICATION OF WELDING DEFECTS

- ❑ Solid inclusion- includes slag, metal oxides, tungsten, wagon track, etc
- ❑ Imperfect shape -under cut, under fill, over lap, excessive penetration, improper bead shape, etc
- ❑ Miscellaneous defects – includes arc strike, excessive spatter, rough surface, uneven ripples, etc





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CLASSIFICATION OF WELDING DEFECTS

All these defects fall under two categories-

②Visual defect /Surface weld defect/External defect

–surface cracks

–over laps

–under cuts

–under fills

–excessive penetration

–surface porosity

–excessive spatter

–Arc strike, etc

–tungsten inclusion, etc.

③Hidden defect/sub surface weld defect/Internal defect

–lack of fusion

–lack of penetration

–sub surface blow holes/
porosity

–shrinkage cavity

–slag inclusion

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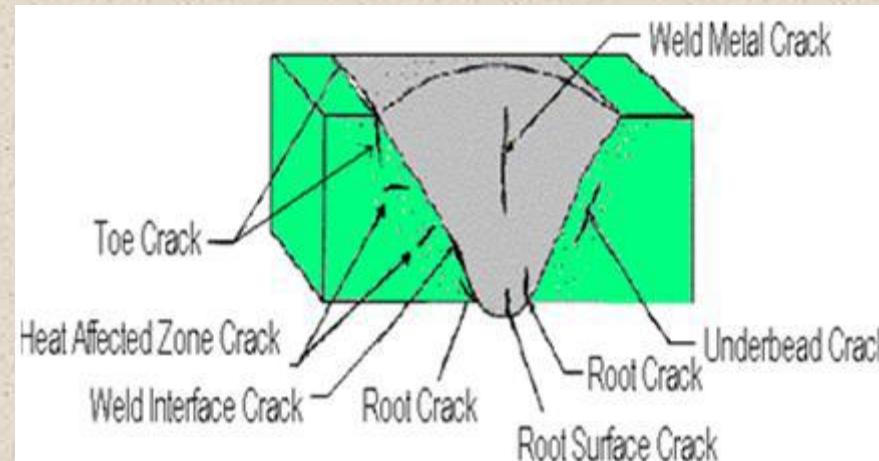




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CRACKS

- A hair line separation in the BM/BM-WM-bdy / WM/HAZ
- May appear:
 - at the root or
 - middle or
 - In the crater
 - surface or
 - subsurface
- Most dangerous of all defects
- Occurs in the WM when localized stresses exceed the UTS of material.
- May be of microscopic or macroscopic sizes.



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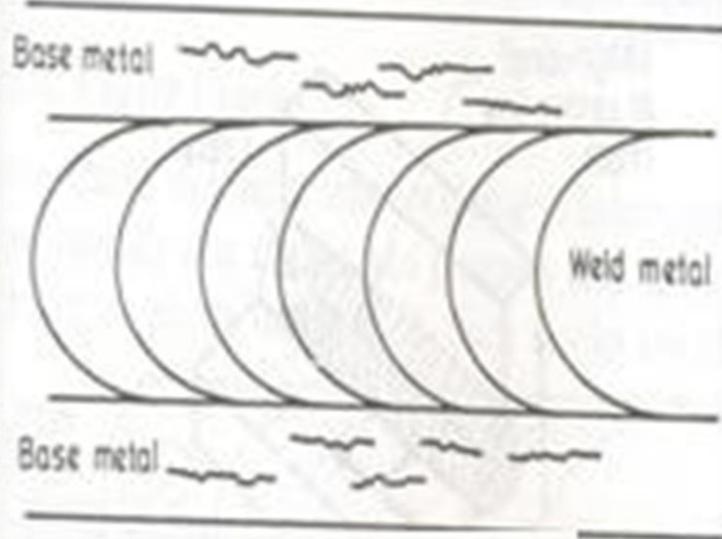




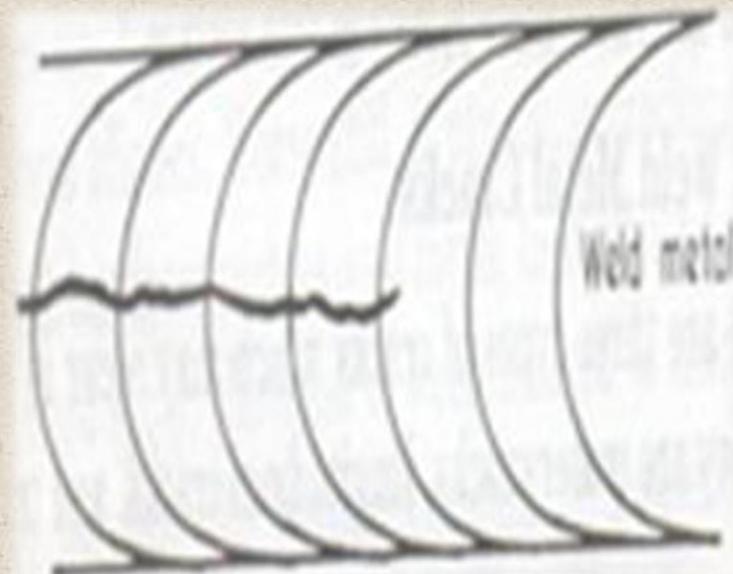
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CRACKS

Long crack in HAZ parallel to weld bead



Long crack in weld metal running through centre of the weld



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CRACKS

Cause:-

- Poor ductility of base metal
- High C & S- content of BM/WM
- High contraction stresses
- Electrode with high hydrogen content

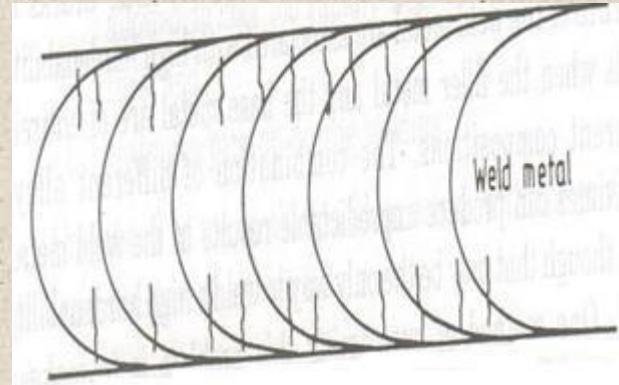
Remedy:-

- Pre- heating
- Mn/S ratio: 18 min.
- Use low H₂ electrode
- Avoid rapid cooling

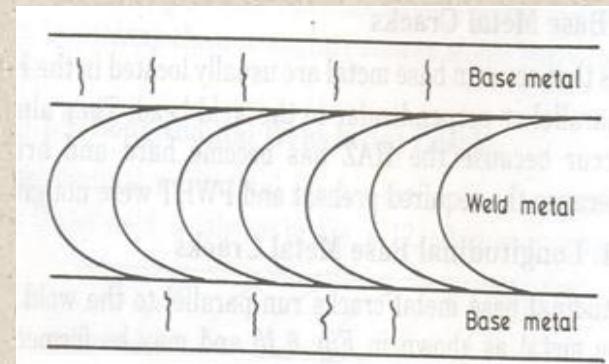
Classification:-

Cracks may be grouped mainly into two categories-

- Hot crack
- Cold crack



Transverse weld crack
running across weld bead



transverse base metal crack
generally in high strength steel

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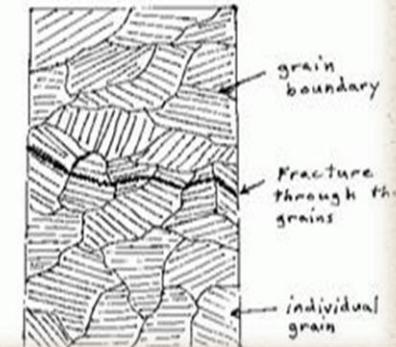
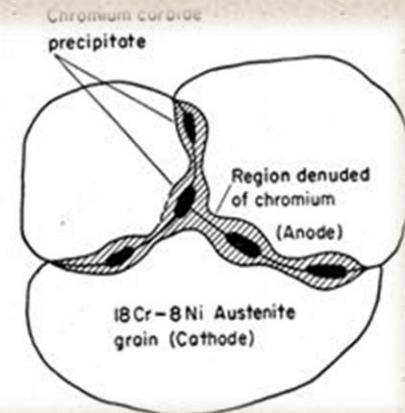


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HOT CRACKS

- Crack in the weld that occurs just after the welds are completed and sometimes while the welds are being made.
- Develops at high temperatures
- Propagates between the grains of the material (intercrystalline)
- Occurs in the weld metal & sometimes in HAZ.
- “solidification crack” (weld metal)
- “liquation crack” (HAZ)

Intercrystalline crack



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HOT CRACKS

Cause:-

- High residual stresses in weld metal
- Low weld ductility
- Too high welding current
- High thickness of work piece (thicker the work piece, faster the cooling rate)
- high ratio of S & P with low Mn content, high C & Ni content (high harden ability)

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HOT CRACKS

Prevention:

- Controlling composition of the metal ($S<0.007\%$) to be welded
- Using filler metal with proper composition & low tensile strength
- Pre- heat
- reduces rate of cooling
- not essential for Austenitic SS (martensite does not occur).

Repair:

- Remove and re-weld





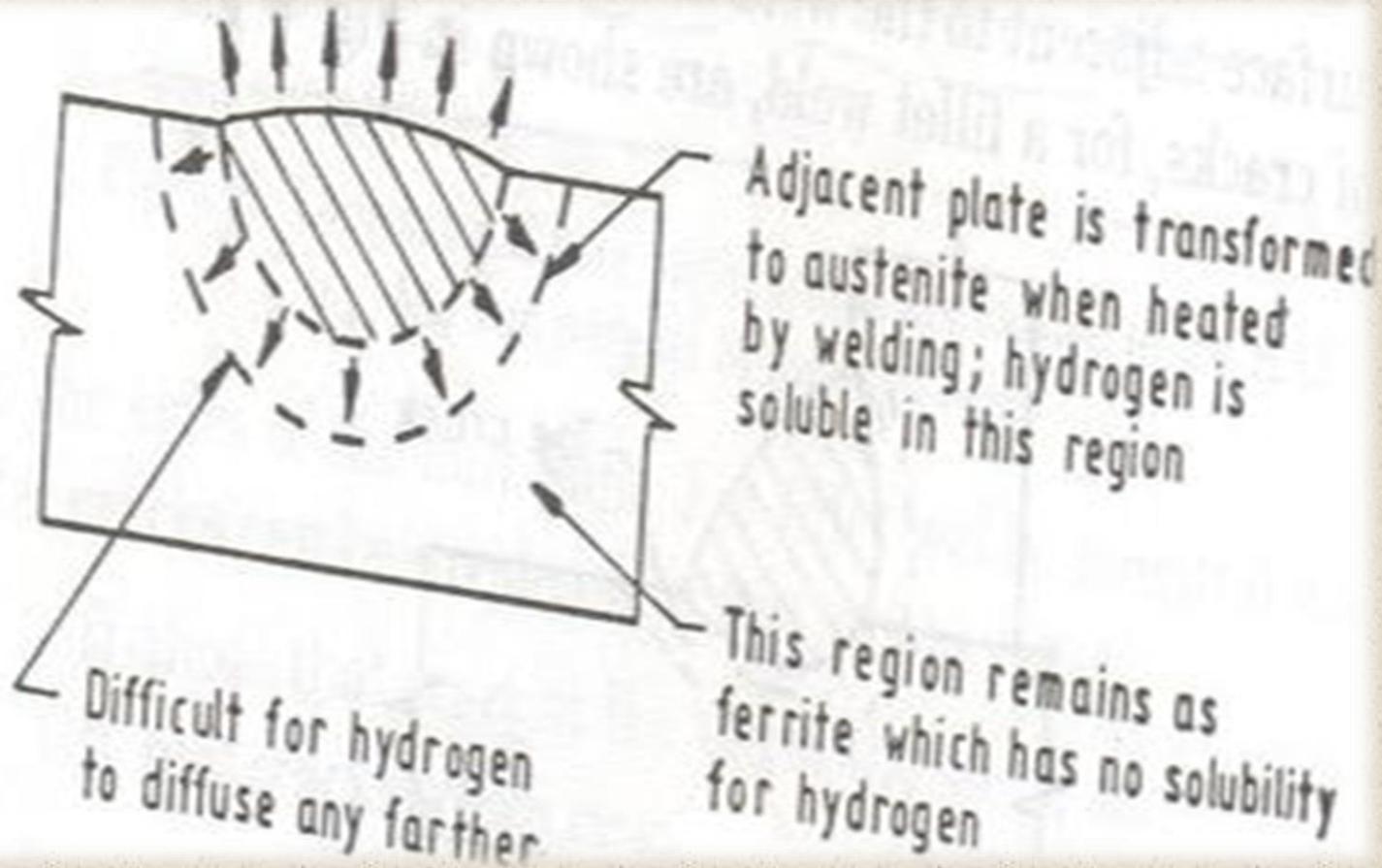
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COLD CRACK

- Occurs after the metal has completely solidified (at temp -1000C to 2000C)
- Can occur several days after weld
- Occurs in C-steel, low & high alloy steel
 - propagates both between grains and through grains.
 - often associated with non-metallic inclusion (elongated MnS).
 - occurs in both weld metal and HAZ but generally in HAZ



COLD CRACK



Movement of H₂ during arc welding

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COLD CRACK

Cause-

- Hydrogen pick up during welding
 - Source of hydrogen:-
- Moisture in base metal & welding electrodes
- Surface contaminated with organic substances
- Surrounding atmospheres
- Phase changes (e.g. formation of martensite) during cooling

Prevention:

- Controlling welding parameters:-
- proper pre-heating:
 - reduces diffusion of H₂
 - ensures no moisture
- Post-welding treatment:
 - stress relief.

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COLD CRACK

- Clean joint from rust
- Use proper welding processes and consumables:
 - Low strength filler metals.
 - Use low hydrogen type baked electrode
- Repair:
 - Remove and re weld.

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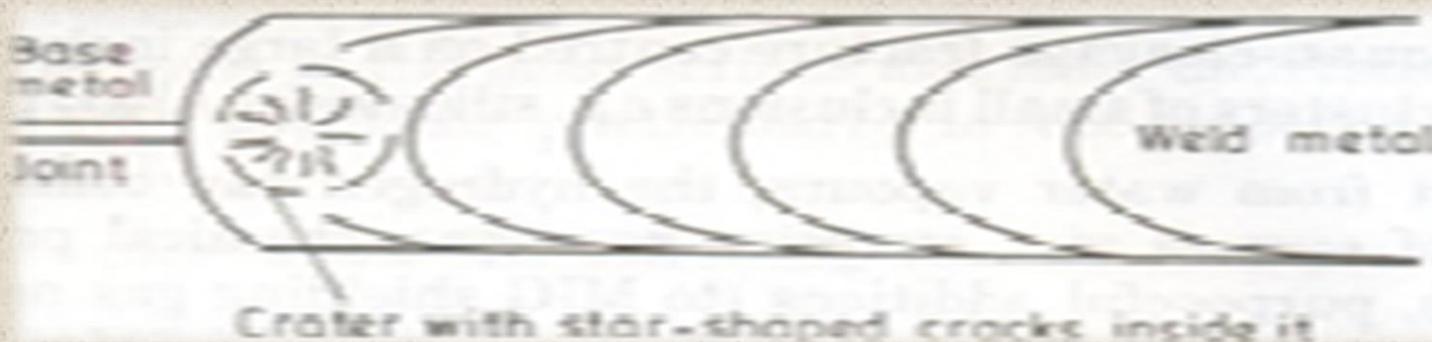


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Crater Crack/Star Crack

"A depression left in weld metal where the arc was broken or the flame was removed or electrode was changed".

- They are hot cracks
- Occurs at the crater of the weld
 - usually star shaped, but may have other shapes.
 - most frequently found in austenitic SS (high thermal coefficient).



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Crater Crack/Star Crack

Cause:

- The centre of weld pool becomes solid before the outside, pulling the centre apart during cooling.
- High current (deep crater)

Prevention:

- can be minimised by filling craters to a slightly convex shape prior to breaking the welding arc.
- may be avoided through improved welding skill

Repair:

– remove and re weld using appropriate procedure.

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Porosities/Blow Holes

“Porosity is a group of small voids, whereas blow holes are comparatively bigger hole or cavity caused by entrapment of gases [gases:H₂,CO,CO₂,N₂ & O₂ from coating ingredients in the electrode or moisture, oil, grease, rust, etc on BM] within the solidified weld”.

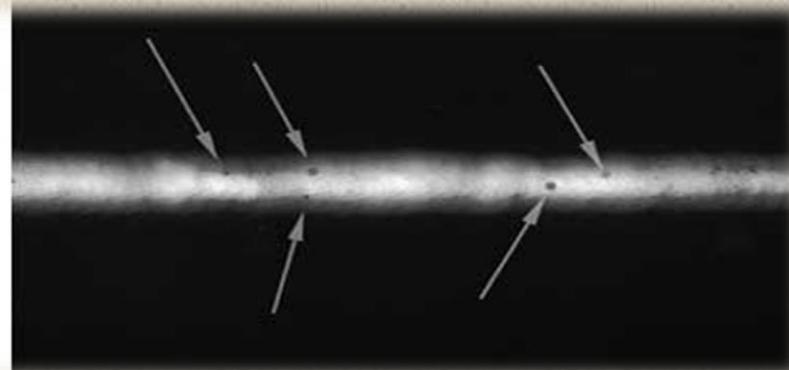
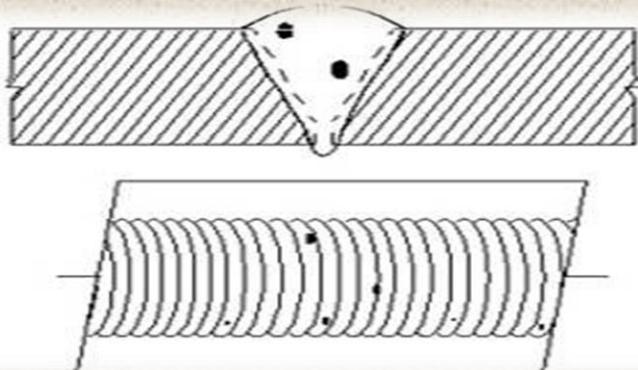
- Porosity can occur on or just below the surface of a weld.
- Porosity in the weld and HAZ may lead to cracking.



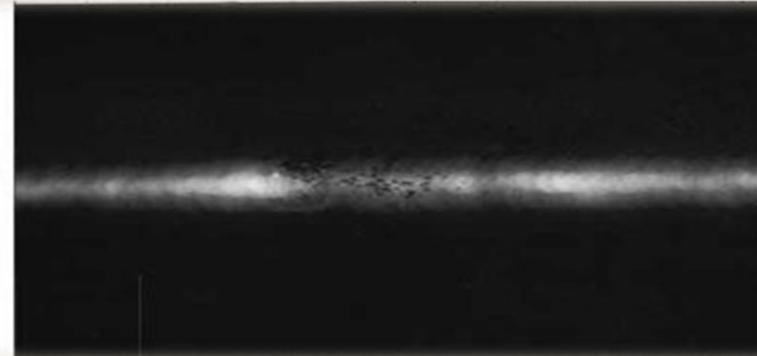
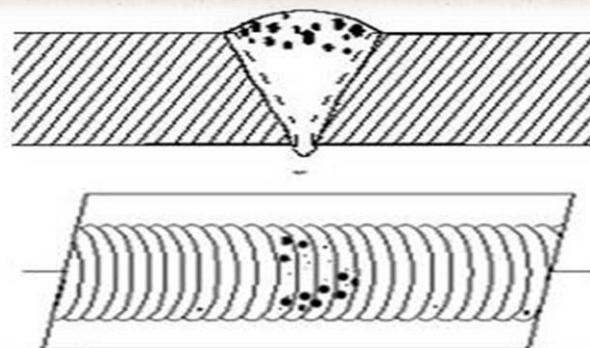


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Porosities / Blow Holes



Gas porosity or blow holes



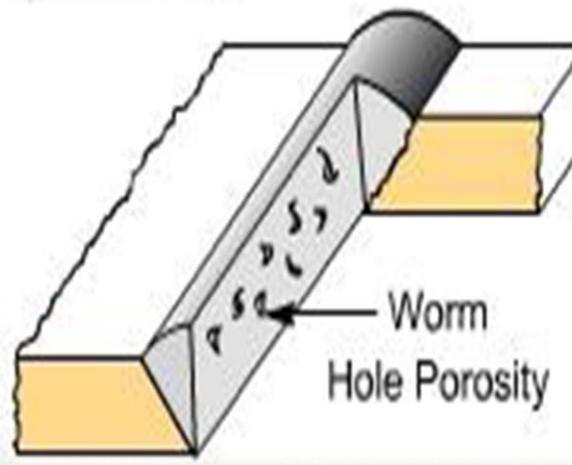
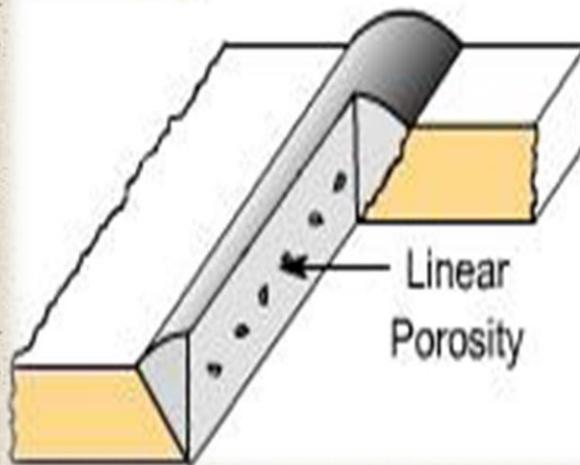
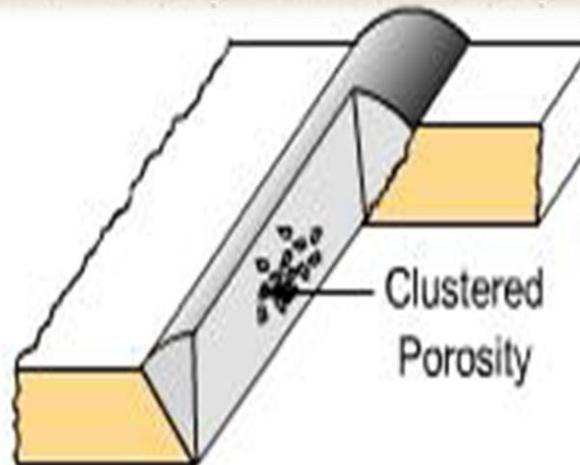
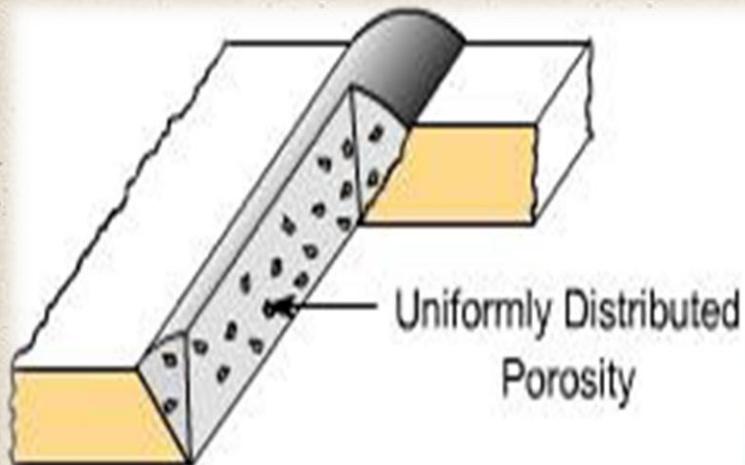
cluster porosity

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Porosities / Blow Holes





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Cause:

- Work piece or electrode contains/contaminated with:-
 - High sulphur & carbon
 - Excessive moisture, rust or scale, oil, grease, etc
- Atmospheric gases [N₂, excessive O₂ (Al-welding)]
- Anodising coating on Al (contains moisture)
- Long arc
- Fast solidification rate

Porosities / Blow Holes

Prevention:

- Preheat
- Maintain proper arc length
- Use low hydrogen electrode
- Use recommended procedure for baking & storing electrodes
- Clean joint surfaces & adjacent surfaces





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Under Cut

“A defect that appears as a groove formed in the BM adjacent to the toe of a weld along the edge of the weld & left unfilled by the weld metal”.

- Generally located parallel to the junction of weld metal & base metal at the toe or root of the weld
- Reduces the cross-sectional thickness of the base metal
- Acts as stress raiser in fatigue loading

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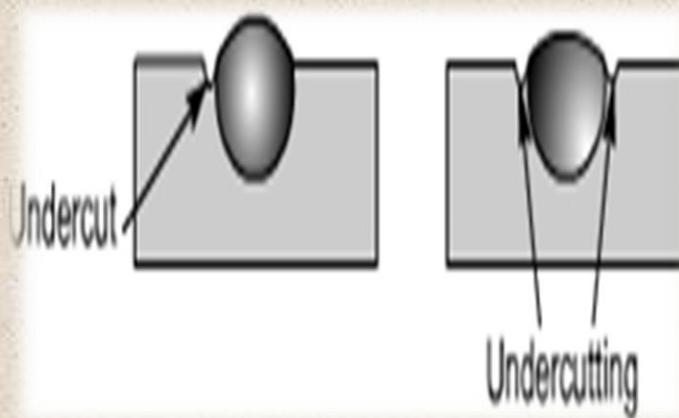
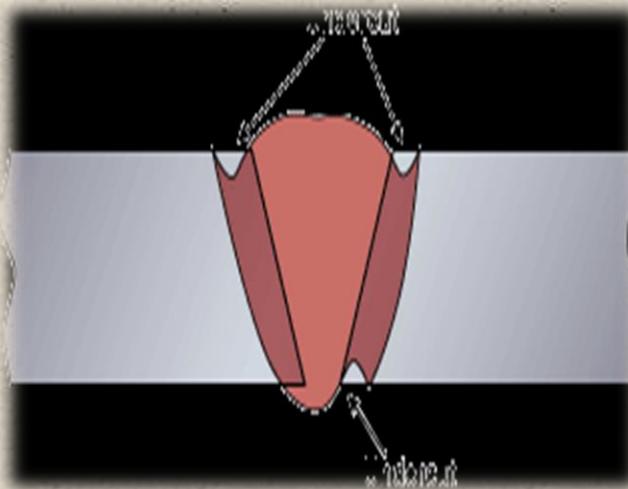
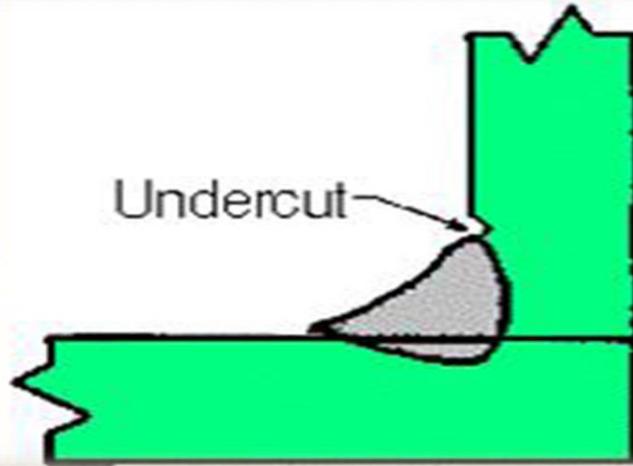
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Under Cut



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Under Cut

Cause:

- High welding current & arc voltage
- Too large electrode dia
- Incorrect electrode angle
- Longer arc length Prevention:
 - Use prescribed welding current for electrode size.
 - Adjust electrode angle to fill undercut area.
- Correct travel speed, arc length, etc. Repair:
 - Gouge & weld with low hydrogen electrode

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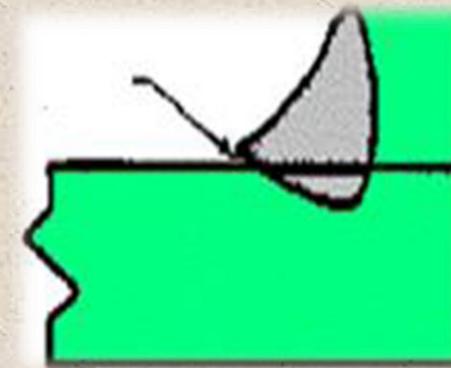
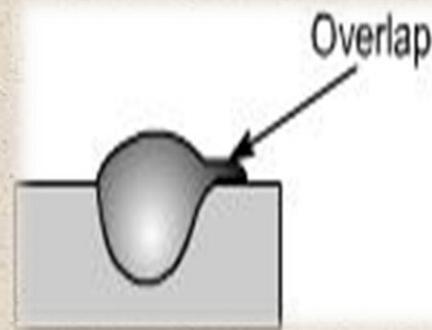
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“An imperfection at the toe of weld caused by over flow of weld metal on the surface of parent metal without fusion”

(protruded weld metal beyond the toe)

- Tends to produce mechanical notch
- Starts a crack at the sharp point where the weld metal and base metal come together at the over-lapped surface

Over Laps





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Over Laps

Cause:-

- current too low
- Too large deposition in a single run
- Longer arc
- slow arc travel speed.

Prevention:

- Proper welding technique
- Use proper size of electrode

Repair:

- Overlap must be removed to blend smoothly into the base metal.

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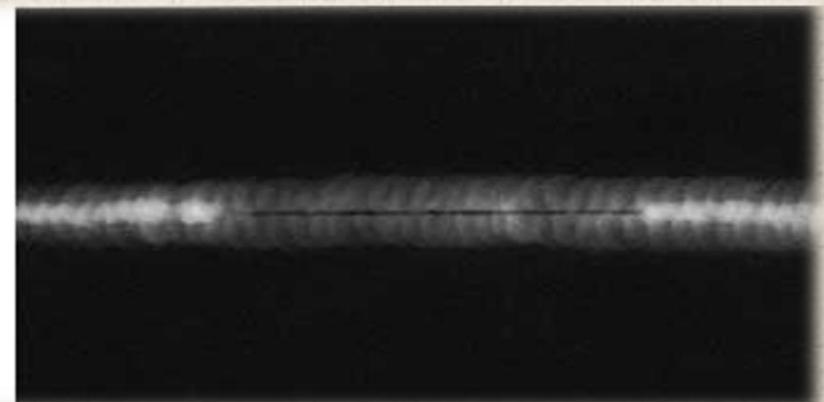
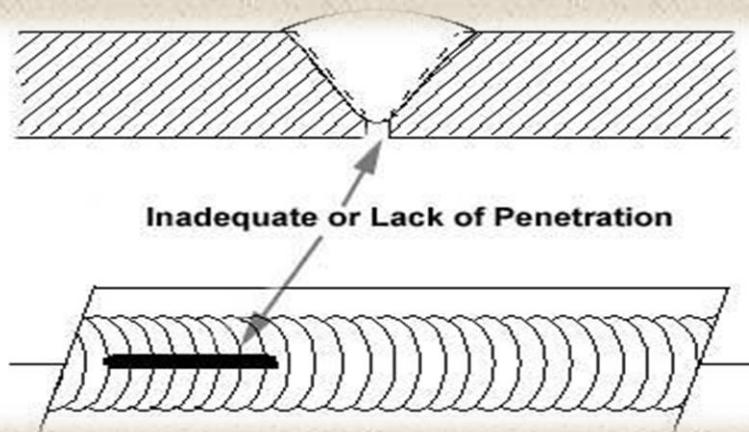
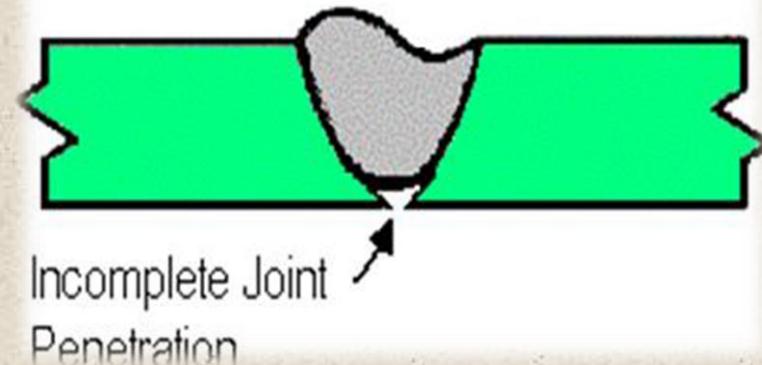


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Lack Of Penetration

"Improper penetration of weld metal through the thickness of joint or weld metal not extending to the required depth into the joint root"

- Acts as stress riser from which a crack may propagate



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Lack Of Penetration

Cause –

- Root gap too small
- high welding speed
- Low heat input
- Too large electrode dia

Prevention:

- Proper joint preparation
- Proper heat input & welding speed
- **Use suitable size of electrode**

Repair:

- Back gouge and back weld or remove and reweld.

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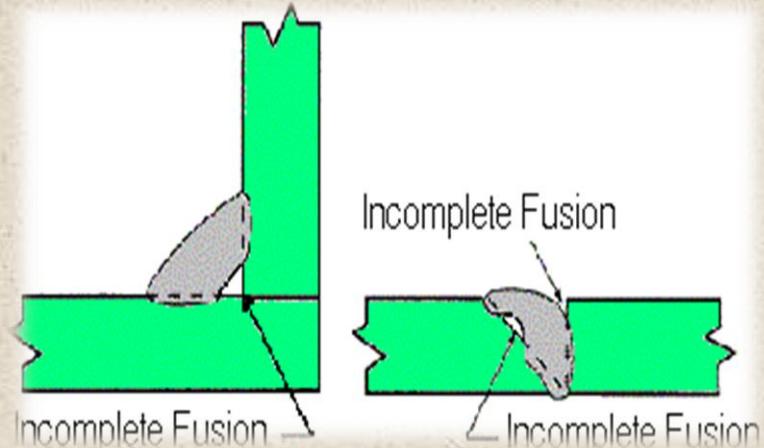


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“Lack of complete melting/ fusion of some portion of the weld metal in a joint”

- May be at the root, sides or between two runs.
- Reduces the strength of welds & makes welded structures unreliable

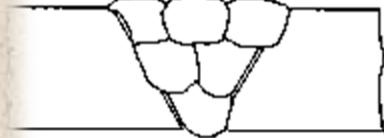
Lack Of Fusion



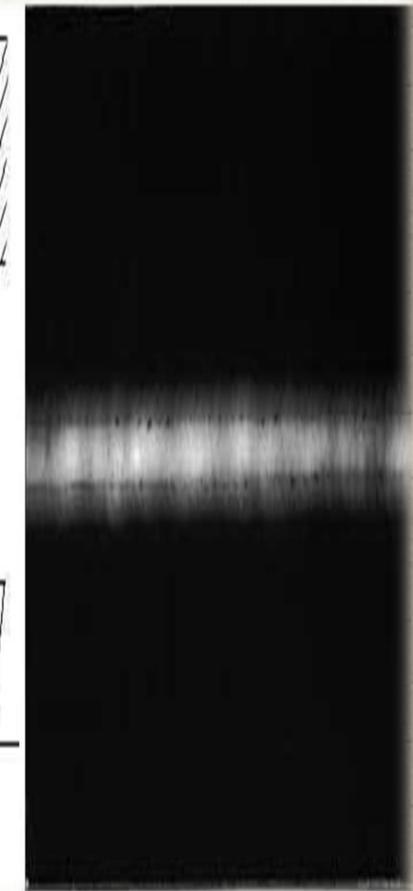
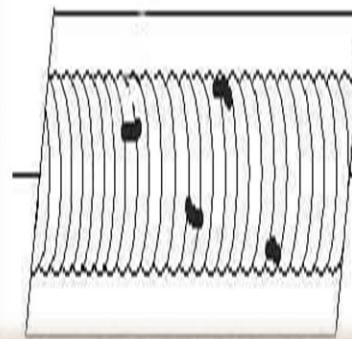
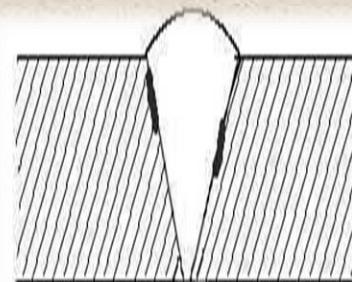
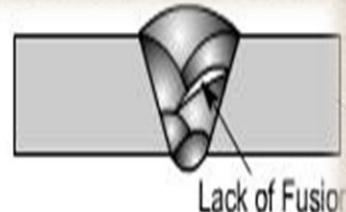
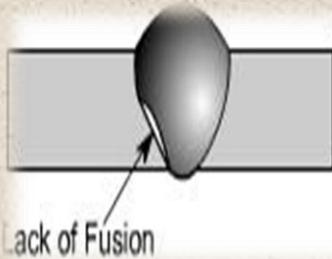


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Lack Of Fusion



lack of fusion between passes



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Lack Of Fusion

Cause:

- Low welding current
- Excess welding speed
- Unfavourable heat input

Prevention:

- Maintain proper current & welding speed
- Proper cleaning of each bead

Repair:

- Chipping back & re-welding

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“Weld metal lying outside the plane joining the toes”

- Makes notches that create stress concentration.
- An economic waste

Cause :-

- Too wide a root gap
- Too high welding current
- Slow travel speeds
- Large size electrodes

Excessive Penetration/Icicles



Excessive penetration in root run of a groove butt weld

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Excessive Penetration/Icicles

Prevention:

- Correct the root opening and root face
- Reduce the wire-feed speed

Repair:-

- Remove and re-weld

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Spatter

“Small globular metal drops / particles thrown out during welding & stick to the BM surfaces along its length”.

- Metal lost
- Do not form a part of the weld.
- Excessive spatters unacceptable.



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Spatter

Cause –

- Excessive arc current
- Excessive long arc
- Improper shielding gas
- Electrodes coated with improper flux ingredients
- Damp electrodes

Prevention:

- Correct welding current for type & size electrode used.
- Correct proper arc length & use correct arc voltage
- Spatter cure SC-07(Non-toxic, non-pollutant, water based inorganic anti-spatter flux)
- can easily be removed either by hair brush or by washing.

Repair:

- Remove by grinding or sanding.

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Inclusion

“Metallic or non metallic solid material entrapped within the WM, between weld passes or between WM & BM”.

- May be in the form of slag or any other foreign material, which does not get a chance to float on the surface of the solidifying WM
- H₂: the most undesirable inclusion (causing: cold crack)
- Lowers the strength of joint & make it weaker
- Non-metallic inclusion:-
 - Most dangerous
 - May be sulphide, oxide, silicate or aluminate type
 - Acts as stress raiser
- Slag inclusions are elongated or globular pockets of metallic oxides and other solid compounds.

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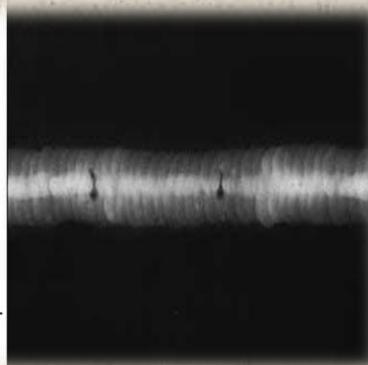




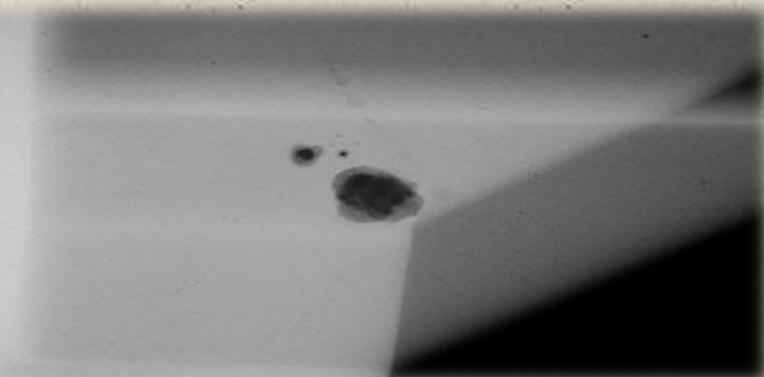
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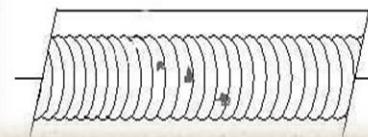
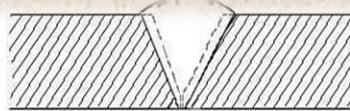
Slag inclusion



Slag inclusion



Sand inclusions



Oxide inclusions
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Inclusion

Possible causes for slag inclusion:

- Inadequate cleaning of weld metal between passes
- Rapid rate of welding
- Too large electrode
- improper current
- Long arcs

Prevention:

- Maintain proper current & heat input
- Proper cleaning of weld

Repair:

- chip back & re-weld

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Metallic Inclusion

Entrapped droplets of tungsten in welds in TIG welding.

–extremely brittle & can fracture easily under stress.

Cause –

- Dipping of tungsten electrode into molten weld pool
- Use of heavy current
- Over heating & melting of W- electrode
- Use of oxygen contaminated shielding gas

Prevention:

- Avoid contact between the electrode & the work
- Use larger electrode
- **Repair:** Grind out and re-weld

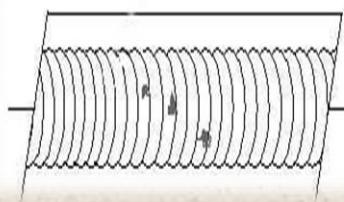
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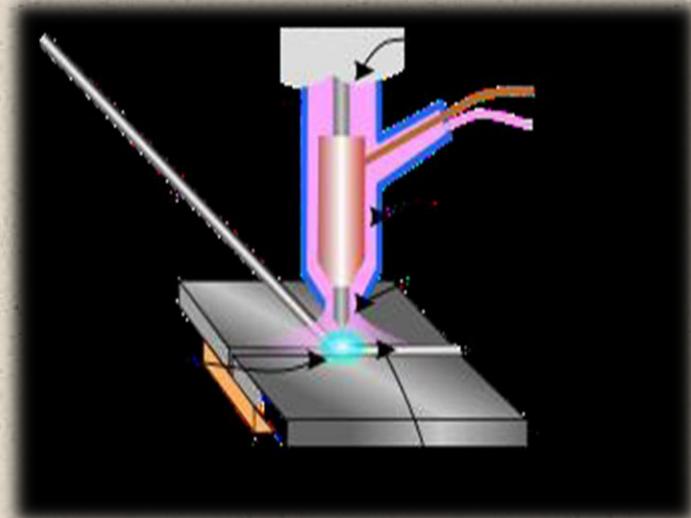


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Metallic Inclusion



W-inclusion



TIG Welding

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Arc Strike

“Localised HAZ”

When a welder accidentally strikes the electrode or the electrode holder against the work, usually adjacent to the weld, causing an unwanted arc. Such spots are referred to as “arc strikes” which can initiate failure in bending or cyclic loading

–Must be avoided

- The repair of such damage may be difficult & costly, involving chipping & pre heating before re welding
- If this is not an option then the arc spot can be post heated



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Wagon Track

“Linear slag inclusions along the axis of weld”

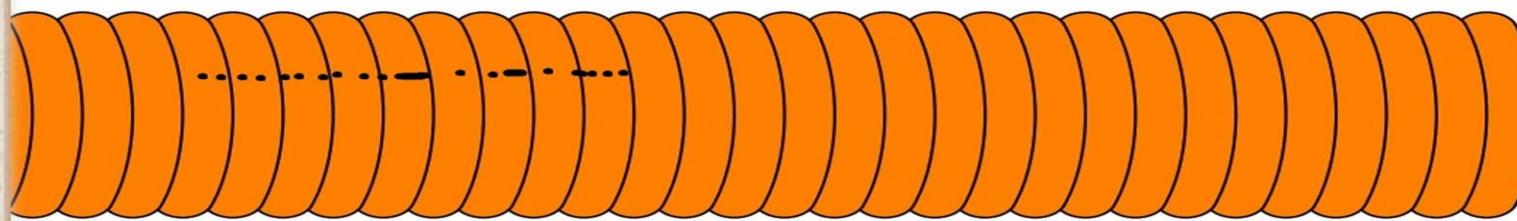
Cause:

- Improper technique

Prevention:

- remove slag from previous passes.

WAGON TRACKS



www.weldingandndt.com

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“The holes burned through the parent metal in a single pass weld or the root run in multi run welds”

- seldom occurs

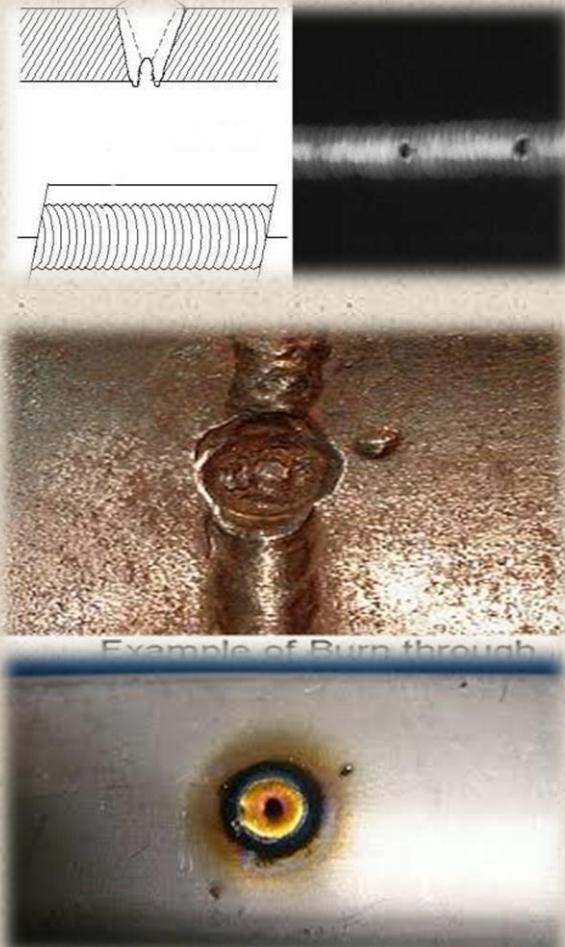
Cause:-

- Excessive welding current with low welding speed
- Insufficient root face
- Excessive root gap

Repair:

- Remove and re-weld
- PWHT

Burn-through



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“A cavity formed by shrinkage of weld metal during its solidification”.

–Seldom occurs

Shrinkage Cavity Or Concentration Cavity



Shrinkage cavity

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Question and Answer Session

- Please ask your questions through Chat

- Mail ID – rohitraut@adorians.com
- Mobile - +91 9011150793

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PASSION FOR WELDING SINCE 1951



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Thank
you!!

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